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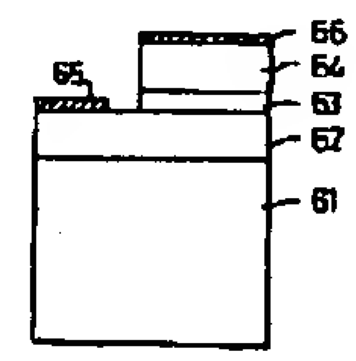
(54) **SEMICONDUCTOR LIGHT EMITTING ELEMENT**

(57) Abstract:

PURPOSE: To manufacture the highly efficient semiconductor light emitting element over the broad wavelength region extending from visible to ultraviolet rays by a method wherein a specific layer is provided between a light emitting layer and a growing substrate.

CONSTITUTION: A specific layer represented by the formula II is provided between a light emitting layer 63 and a growing substrate 61. Next, the light emitting layer 63 having at least one layer represented by the formula I is held between n-type and p-type GaN current injection layers 62 and 64 represented by the formula III. Through these procedures, the electrons and holes injected in the light emitting layer 63 are enclosed therein without running into the current injection layer 62, 64 thereby enabling the light in high outer quantum efficiency to be emitted. That is, even if n-type and p-type current injection layers 62 and 64 are doped in high concentration of e.g. 10^{18}-$10^{19}cm^{-3}$, the title light emitting element having excellent current versus voltage characteristic can be manufactured without affecting the purity of the light emitting spectrum due to the distinct separation between the light emitting region 63 and the current injection regions 62, 64.



$$In_{1-x-y}Ga_xAl_yN \ (x+y<1,\ 0\leq x,y\leq 1) \qquad \mathrm{I}$$

$$Ga_{1-x'}Al_{x'}N \ (0\leq x'\leq 1) \qquad \mathrm{II}$$

$$In_{1-x''-y''}Ga_{x''}Al_{y''}N \ (x''+y''\leq 1,\ 0\leq x'',y''\leq 1) \qquad \mathrm{III}$$

[Claim(s)]

[Claim 1] It is [Formula 1] in a luminous layer.

$$In_{1-x-y}Ga_xAl_yN\ (x+y<1,\ 0\leqq x,y\leqq 1)$$

A layer is set to the semi-conductor light emitting device included further at least, and it is [Formula 2] between a luminous layer and a growth substrate.

$$Ga_{1-x'}Al_{x'}N\ (0\leqq x'\leqq 1)$$

The semi-conductor light emitting device characterized by preparing a layer.

[Claim 2] [Formula 1] in said luminous layer [Formula 3] with bandgap energy touch a layer and larger than this

$$In_{1-x''-y''}Ga_{x''}Al_{y''}N\ (x''+y''\leqq 1,\ 0\leqq x'',y''\leqq 1)$$

The semi-conductor light emitting device according to claim 1 characterized by having a layer.

[Detailed Description of the Invention]

[0001]

[Industrial Application] Since this invention is visible, it relates to the structure for compound semiconductor light emitting devices which emits light by ultraviolet.

[0002]

[Description of the Prior Art] In order to obtain efficient current impregnation luminescence in a semi-conductor light emitting device, it is important that the electron and electron hole which were poured in from p mold and n mold current impregnation layer carry out radiation recombination efficiently in a luminescence field. Conventional [Formula 1] In a ******** semi-conductor light emitting device, there were the following troubles about the structure. Conventional [Formula 1] As the 1st example of a ******** semi-conductor light emitting device, the block diagram of GaN gay junction diode is shown in drawing 6 R> 6. For silicon on sapphire and 12, as for a p mold GaN layer and 14, an n mold GaN layer and 13 are [11 / n lateral electrode and 15] p lateral electrodes among drawing. It is common in n type layer 12 to use GaN which formed undoping or the Si dope GaN into low resistance by after [Mg doping] electron beam irradiation or heat annealing in p type layer 13. With this structure, the depletion layer formed in a pn

junction interface serves as a luminescence field, and only the electron and electron hole which carried out radiation recombination within the depletion layer contribute to luminescence. The 1st trouble of this structure is that the electron poured in into the depletion layer and most part of an electron hole do not recombine within a depletion layer, but are spread to n type layer 12 and p type layer 13. Consequently, improvement in luminous efficiency cannot be desired with this structure. The 2nd trouble of this structure is that luminescence from a deep level appears in an emission spectrum, and a spectrum with high purity is not obtained, when high concentration doping is performed in n type layer 12 and p type layer 13 for series resistance reduction. Consequently, the good current pair voltage characteristic and a good emission spectrum property cannot be reconciled.
[0003] [Formula 1] of the former [drawing 7] The block diagram of GaAlN/GaN heterojunction diode was shown as the 2nd example of a ******** semi-conductor light emitting device. For an n mold GaAlN current impregnation layer and 23, as for a p mold GaAlN current impregnation layer and 25, a GaN luminous layer and 24 are [21 / silicon on sapphire and 22 / n lateral electrode and 26] p lateral electrodes among drawing. With this structure, since it has structure which sandwiched the GaN luminous layer 23 from this in the large n mold GaAlN current impregnation layer 22 and the p mold GaAlN current impregnation layer 24 of bandgap energy, the electron and electron hole which were poured into the GaN luminous layer 23 are confined in the GaN luminous layer 23, without being spread to the n mold GaAlN current impregnation layer 22 and the p mold GaAlN current impregnation layer 24. Moreover, even if it performs high concentration doping in the n mold GaAlN current impregnation layer 22 and the p mold GaAlN current impregnation layer 24 for series resistance reduction, it has the advantage of not doing effect in the emission spectrum of the GaN luminous layer 23. The structure which used the GaAlN/GaN single quantum well or the multiplex quantum well as a luminous layer instead of the GaN luminous layer 23 of drawing 7 , and attained efficient-ization of luminous efficiency as structure which improved the structure of drawing 7 is also well-known. With this structure, a GaAlN layer with aluminum presentation lower than the n mold GaAlN current impregnation layer 22 and the p mold GaAlN current impregnation layer 24 is chosen as a barrier layer of a GaAlN/GaN quantum well. However, with the

structure which improved the structure of drawing 7 , and this, as stated above, since GaN, or GaAlN the mixed crystal of 3 yuan is used as a luminous layer, luminescence wavelength can be chosen only within the limits of 200-370nm.

[0004] Conventional [Formula 1] As the 3rd example of a ******** semi-conductor light emitting device, the block diagram of InGaAlN/InGaN heterojunction diode is shown in drawing 8 . For an n mold InGaAlN current impregnation layer and 33, as for a p mold InGaAlN current impregnation layer and 35, an InGaN luminous layer and 34 are [31 / silicon on sapphire and 32 / n lateral electrode and 36] p lateral electrodes among drawing. Here, the bandgap energy of the presentation of the n mold InGaAlN current impregnation layer 32 and the p mold InGaAlN current impregnation layer 34 is larger than the InGaN luminous layer 33, and it is chosen so that the lattice constant may have consistency in the InGaN luminous layer 33. With this structure, since it has structure into which bandgap energy inserted the InGaN luminous layer 33 from this in the large n mold InGaAlN current impregnation layer 32 and the p mold InGaAlN current impregnation layer 34, it is shut up in the InGaN luminous layer 33, without the electron and electron hole which were poured into the InGaN luminous layer 33 flowing into the n mold InGaAlN current impregnation layer 32 and the p mold InGaAlN current impregnation layer 34. Moreover, in order to reduce series resistance, even if it performs high concentration doping in the n mold InGaAlN current impregnation layer 32 and the p mold InGaAlN current impregnation layer 34, it has the advantage of not doing effect in the emission spectrum of the InGaN luminous layer 33. Furthermore, with this structure, since InGaAlN the mixed crystal of 4 yuan is used as a luminous layer, luminescence wavelength can be changed in 200-600nm. Furthermore, with this structure, since the n mold InGaAlN current impregnation layer 32, the InGaN luminous layer 33, and the p mold InGaAlN current impregnation layer 34 are carrying out lattice matching mutually, component degradation by the nonluminescent recombination center or crystal defect resulting from grid mismatching does not take place. However, plural mixed crystal containing In [** 1] Compared with ** GaN or GaAlN, crystallinity is inadequate, and there was a problem that production of a light emitting device with a good emission spectrum property was difficult.

[0005]

[Problem(s) to be Solved by the Invention] It was proposed in order that this invention might solve the above trouble, and since the purpose is visible, it is to offer the efficient semi-conductor light emitting device in the large wavelength region covering ultraviolet. It is [Formula 1] used for the luminous layer the top where it is possible for this invention to shut up an electron and an electron hole into a luminous layer when explaining in full detail furthermore. It is in offering the semi-conductor light emitting device whose crystallinity of a layer improves automatically.

[0006]

[Means for Solving the Problem] The semi-conductor light emitting device of this invention is [Formula 1] in a luminous layer. A layer is set to the semi-conductor light emitting device included further at least, and it is [Formula 2] between a luminous layer and a growth substrate. It is characterized [main] by preparing a layer. Moreover, the 2nd main description of this invention is [Formula 1] in said luminous layer. [Formula 3] from which this and a lattice constant differ in contact with a layer It is in having prepared the layer. The point which contains at least the layer which contains In in a luminous layer further differs from the conventional GaN gay junction diode and GaAlN/GaN heterojunction diode. Furthermore, it differs from the conventional gay junction diode in that it has a heterojunction interface in a luminous layer. It differs in that the conventional InGaAlN/InGaN heterojunction diode produces a component under a grid inconsistent condition.

[0007]

[Function] It sets to this invention and is [Formula 2] between a luminous layer and a growth substrate. By preparing a layer, crystallinity can improve and it can deal in the light emitting device which was excellent in the luminescence property compared with the conventional light emitting device.

[0008]

[Example] Next, the example of this invention is explained. The experimental result which became clear in the research which results in drawing 4 and drawing 5 at this invention is shown. Drawing 4 is drawing showing the X diffraction profile of the In0.1 Ga0.9 N layer of 0.5 micrometers of thickness, and when (a) grows an In0.1 Ga0.9 N layer directly on

sapphire, (b) corresponds, when it grows up through GaN of 5 micrometers of thickness on sapphire. The full width at half maximum of the X diffraction profile of an In0.1 Ga0.9 N layer which grew through GaN on sapphire is sharply reduced with 1.5 minutes to the full width at half maximum of the X diffraction profile of an In0.1 Ga0.9 N layer which grew directly on sapphire being 20 minutes.

[0009] Drawing 5 is drawing showing the photoluminescence spectrum of the same sample as drawing 4 , and when (a) grows an In0.1 Ga0.9 N layer directly on sapphire, (b) corresponds, when it grows up through GaN of 5 micrometers of thickness on sapphire. The photoluminescence spectrum of the In0.1 Ga0.9 N layer which grew through GaN on sapphire turns into a photoluminescence spectrum of the In0.1 Ga0.9 N layer which grew directly on sapphire only from luminescence from from near the band edge with a peak of 360nm to luminescence from a deep level appearing. The above effectiveness was not based on the presentation x of In1-x Gax N, but was observed to all x of 0<=x<=1. As mentioned above, the membraneous quality of an InGaN layer improves remarkably by growing up through GaN. Moreover, [Formula 5]

$$Ga_{1-x''}Al_{x''}N\ (0 \leqq x'' \leqq 1)$$

The same effectiveness was observed even if it grew up InGaN through the layer. Although drawing 4 and drawing 5 showed the result at the time of using a sapphire (0001) side as a substrate, even if it used other ingredient substrate or other field bearing substrates, the same result was completely obtained. This is the plural mixed crystal [** 1] containing In. A layer is essentially [Formula 6].

$$Ga_{1-x}Al_{x}N\ (0 \leqq x \leqq 1)$$

Compared with a layer, it is because crystal quality is inadequate. Next, the example of this invention performed based on the above-mentioned experimental result is explained. In addition, an example is one instantiation, it is the range which does not deviate from the pneuma of this invention, and it cannot be overemphasized that various modification or amelioration can be performed.

[0010] [Example 1] (grid mismatching double hetero structure and single quantum well structure)

Drawing 1 is drawing showing the structure of the 1st example of this invention, and, for 5

micrometers of thickness, the Si dope n mold GaN current impregnation layer of concentration-of-electrons 1019cm-3, and 63, as for 2 micrometers of thickness, the Mg dope p mold GaN current impregnation layer of hole concentration 1018cm-3, and 65, the undoping In0.1 Ga0.9 N luminous layer of 0.5 micrometers of thickness and 64 are [61 / a sapphire (0001) substrate and 62 / n lateral electrode and 66] p lateral electrodes. The electron and the electron hole were poured into the luminous layer 63 by applying a forward electrical potential difference to 66 to an electrode 65. Consequently, it started, the current pair voltage characteristic of electrical-potential-difference 4V was acquired, and luminescence which has a luminescence peak only in wavelength the band of 380nm has been observed. The maximum optical output was 1.6mW and external quantum efficiency was 2%. Moreover, luminescence wavelength was able to be formed into long wavelength to 600nm by changing the presentation of the InGaN luminous layer 63.

[0011] With this structure, since it has the structure where bandgap energy sandwiches the undoping In0.1 Ga0.9 N luminous layer 63 from this in large n mold and the p mold GaN current impregnation layers 62 and 64, the electron and electron hole which were poured into the luminous layer 63 are shut up in a luminous layer 63, without flowing into the current impregnation layers 62 or 64, and high luminescence of external quantum efficiency is obtained as mentioned above. Thus, since the luminescence field and the current impregnation field are separated clearly, even if it performs high concentration doping called 1018-1019cm-3 in n mold and p mold current impregnation layers 62 and 64, a component with the good current pair voltage characteristic can be produced, without affecting the purity of an emission spectrum. Moreover, with this structure, since the InGaN layer is used as a luminous layer, luminescence wavelength can be changed in 360-600nm. In spite of using InGaN for the luminous layer in this structure, the greatest cause that the above good properties are acquired is in the point of growing up on the crystalline good n mold GaN current impregnation layer 62, about the InGaN luminous layer 63. Especially in the configuration of drawing 1 , if thickness of a luminous layer 63 is set to 10nm or less, it will become below the critical thickness that the crystal structure defect resulting from grid mismatching generates, and the crystallinity of a luminous layer 63 will improve remarkably. Consequently, a component property improves and a

component life is also prolonged. Thus, in the light emitting device with the thin thickness of a luminous layer, the quantum locked-in effect showed up and luminescence wavelength was shifted to 375nm. It is [Formula 6] although it said here that GaN is used as 62. ******** is also good. Moreover, as a luminous layer, although InGaN was used, it is [Formula 4].

$$In_{1-x-y}Ga_xAl_yN \quad (0 \leq X, Y \leq 1, X+Y<1)$$

But the good thing is clear.

[0012] [Example 2] (separation ****** single quantum well structure)

Drawing 2 is drawing showing the structure of the 2nd example of this invention, and is set to drawing. A sapphire (0001) substrate and 72 71 Si dope n mold GaAlN current impregnation of 5 micrometers of thickness, and concentration-of-electrons 5x1018cm-3, and an optical confinement layer, 73 2 micrometers of thickness, the Si dope n mold GaN carrier confining layer of concentration-of-electrons 1019cm-3, 74 The undoping In0.1 Ga0.9 N single quantum well luminous layer of 10nm of thickness, For 75, as for 2 micrometers of thickness, Mg dope p mold GaAlN current impregnation of hole concentration 5x1017cm-3 and an optical confinement layer, and 77, 2 micrometers of thickness, the Mg dope p mold GaN carrier confining layer of hole concentration 1018cm-3, and 76 are [n lateral electrode and 78] p lateral electrodes. The electron and the electron hole were poured into the luminous layer 74 by applying a forward electrical potential difference to 78 to an electrode 77. Consequently, it started, the current pair voltage characteristic of electrical-potential-difference 4V was acquired, and luminescence which has a luminescence peak only in wavelength the band of 375nm has been observed. The maximum optical output was 3mW and external quantum efficiency was 2%. Moreover, luminescence wavelength was able to be formed into long wavelength to 600nm by changing the presentation of the InGaN luminous layer 73.

[0013] This structure is the structure which sandwiched the upper and lower sides of an n mold GaN layer, an InGaN layer, and a p mold GaN layer in the p mold GaAlN layer and the n mold GaAlN layer in the component structure of an example 1, and the same effectiveness can completely be expected to have been obtained with the structure of an

example 1. Furthermore, in the structure of an example 1, although optical confinement will become inadequate if thickness of an InGaN luminous layer is made thin with 10nm, with the structure of drawing 2 , the effectiveness of optical confinement shows up by existence of n mold with a refractive index smaller than the n mold GaN layer 73, the InGaN layer 74, and the p mold GaN layer 75 and the p mold GaAlN layers 72 and 76, and a big optical output as mentioned above and high external quantum efficiency can be acquired. although GaN and GaIN were here used for each class which constitutes a component -- bandgap energy -- drawing 2 -- setting -- 74 -- < -- 73 and 75 -- < -- as long as the relation of 72 and 76 is maintained -- [Formula 4] It is clear that ******** is also good.

[0014] [Example 3] (separation ****** multiplex quantum well structure)

Drawing 3 is drawing showing the structure of the 3rd example of this invention, and is set to drawing. A sapphire (0001) substrate and 82 81 Si dope n mold GaAlN current impregnation of 5 micrometers of thickness, and concentration-of-electrons 5x1018cm-3, and an optical confinement layer, 83 2 micrometers of thickness, the Si dope n mold GaN carrier confining layer of concentration-of-electrons 1019cm-3, The multiplex quantum well layer to which 84 carried out the ten-layer laminating of the undoping GaN layer of 10nm of thickness to undoping In0.1 Ga0.9 N of 10nm of thickness by turns, For 85, as for 2 micrometers of thickness, Mg dope GaAlN current impregnation of hole concentration 5x1017cm-3 and an optical confinement layer current impregnation layer, and 87, 2 micrometers of thickness, the Mg dope p mold GaN carrier confining layer of hole concentration 1018cm-3, and 86 are [n lateral electrode and 88] p lateral electrodes. The electron and the electron hole were injected into the multiplex quantum well layer 84 by applying a forward electrical potential difference to 88 to an electrode 87. Consequently, it started, the current pair voltage characteristic of electrical-potential-difference 6V was acquired, and luminescence which has a luminescence peak only in wavelength the band of 375nm has been observed. The maximum optical output was 5mW and external quantum efficiency was 6%. Moreover, luminescence wavelength was able to be formed into long wavelength to 600nm by changing the presentation of the InGaN luminous layer 83. Since this structure is the structure which introduced the InGaN/GaN multiplex quantum well

instead of the InGaN luminous layer 74 of the structure of drawing 2 , when the same operation completely works having been obtained with the structure of drawing 2 , since the number of layers of the InGaN well layer which is a substantial luminous layer is increasing, a big optical output as mentioned above can be obtained. To each class of this example, it is [Formula 1]. It is clear that ******** is also good.

[0015] In all the above-mentioned examples, although the sapphire (0001) side was used as a substrate, even if it uses other ingredient substrate or other field bearing substrates, the same effectiveness can completely be acquired. in order [moreover,] to improve the crystallinity of Ga1-x Alx N (0<=x, y<=1) which exists between a luminous layer and a substrate -- a substrate top -- first -- low ****** -- [Formula 2] If it deposits, it is much more effective.

[0016]

[Effect of the Invention] As explained above, at the structure for semi-conductor light emitting devices of this invention, it is [Formula 1] in a luminous layer. Since the layer is used, luminescence wavelength can be changed in 200-600nm. Moreover, at the structure for semi-conductor light emitting devices of this invention, it is [Formula 2] between a luminous layer and a growth substrate. [Formula 1] used into the luminous layer since it had a layer The crystallinity of a layer improves and it is conventional [Formula 1]. Compared with the light emitting device which used the layer for the luminous layer, the light emitting device which was excellent in the luminescence property is producible. Especially, it is [Formula 1]. If thinner than the critical thickness which the crystal structure defect to which the thickness of a layer originates in grid mismatching generates, crystallinity improves still more remarkably and has the advantage said that a very good light emitting device is producible.

[Brief Description of the Drawings]

[Drawing 1] It is drawing showing the structure of the 1st example of this invention, and InGaN/GaN double hetero structure is shown.

[Drawing 2] It is drawing showing the structure of the 2nd example of this invention, and InGaN/GaN/GaAlN separation ****** single quantum well structure is shown.

[Drawing 3] It is drawing showing the structure of the 3rd example of this invention, and

InGaN/GaN/GaAlN separation ****** multiplex quantum well structure is shown.

[Drawing 4] It is drawing showing the X diffraction profile of sapphire top In0.1 Ga0.9 N, and (a) corresponds, when it does not mind a GaN layer, and (b) minds a GaN layer.

[Drawing 5] It is drawing showing the photoluminescence spectrum of sapphire top In0.1 Ga0.9 N, and (a) corresponds, when it does not mind a GaN layer, and (b) minds a GaN layer.

[Drawing 6] It is drawing explaining the 1st example of the conventional structure for semi-conductor light emitting devices, and the block diagram of GaN gay junction diode is shown.

[Drawing 7] It is drawing explaining the 2nd example of the conventional structure for semi-conductor light emitting devices, and the block diagram of GaAlN/GaN heterojunction diode is shown.

[Drawing 8] It is drawing explaining the 3rd example of the conventional structure for semi-conductor light emitting devices, and the block diagram of InGaAlN/InGaN heterojunction diode is shown.

[Description of Notations]

11 Silicon on Sapphire

12 N Mold GaN Layer

13 P Mold GaN Layer

14 N Lateral Electrode

15 P Mold Electrode

21 Silicon on Sapphire

22 N Mold GaAlN Current Impregnation Layer

23 GaN Luminous Layer

24 P Mold GaAlN Current Impregnation Layer

25 N Lateral Electrode

26 P Mold Electrode

31 Silicon on Sapphire

32 N Mold InGaAlN Current Impregnation Layer

33 InGaN Luminous Layer

34 P Mold InGaAlN Current Impregnation Layer

35 N Lateral Electrode

36 P Mold Electrode

61 Sapphire (0001) Substrate

62 Si Dope N Mold GaN Current Impregnation Layer

63 Undoping In0.1 Ga0.9 N Luminous Layer

64 Mg Dope P Mold GaN Current Impregnation Layer

65 N Lateral Electrode

66 P Mold Electrode

71 Sapphire (0001) Substrate

72 Si Dope N Mold GaAlN Current Impregnation and Optical Confinement Layer

73 Si Dope N Mold GaN Carrier Confining Layer

74 Undoping In0.1 Ga0.9 N Single Quantum Well Luminous Layer

75 Mg Dope P Mold GaN Carrier Confining Layer

76 Mg Dope P Mold GaAlN Current Impregnation and Optical Confinement Layer

77 N Lateral Electrode

78 P Mold Electrode

81 Sapphire (0001) Substrate

82 N Mold GaAlN Current Impregnation and Optical Confinement Layer

83 N Mold GaN Carrier Confining Layer

84 Undoping In0.1 Ga0.9 N/GaN Multiplex Quantum Well Layer

85 Mg Dope P Mold GaN Carrier Confining Layer

86 Mg Dope GaAlN Current Impregnation and Optical Confinement Layer Current Impregnation Layer

87 N Lateral Electrode

88 P Mold Electrode